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Low loss NbTi Superconducting Wires for the SIS100 Main Magnets made by Luvata

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ABSTRACT

The "Facility for Antiproton and Ion Research - FAIR" will be built near the premises of the renowned physical research institute GSI Helmholtzzentrum für Schwerionen-forschung GmbH in Darmstadt Germany. The company Luvata has been the sole supplier for low loss Superconducting wires for the SIS100 main magnets. SIS100 is a ring accelerator (heavy ion synchrotron) with a circumference of 1100 meters to be associated with a complex system of cooler and storage rings and experimental setups. The synchrotron will deliver ion beams of unprecedented intensities and energies.

A total of 1030 km of 25 000 ultrafine filament wire having filament diameters around 3 µm, has been delivered for the project. The OK25000 wire has a CuMn interfilamentary matrix embedded in a high purity copper matrix, all manufactured in house at the premises of Luvata. To guarantee low loss performance Luvata incorporated several technologies to reduce the AC losses.

In this paper we will present the results of the wires electromagnetic performances, including critical current and current density, n-value, twist pitch, effective filament size, and linear resistance compared to the customer specified values.

Index Terms—Low loss superconductors, GSI, FAIR, SIS100

INTRODUCTION

The SIS100 double accelerator ring will need very challenging NbTi superconductors with a resistive matrix to allow for the required performance to meet the science expectations. Luvata Special Products (LSP) together with excellent co-operation of GSI has had the opportunity to provide the project with wires meeting the expectations.

In the beginning of May 2017 Mitsubishi Materials Corporation (MMC) completed the acquisition of Luvata Special Products (LSP) division from Luvata. LSP is now continuing as a part of the Copper Processing business of MMC's Metal Company. This acquisition is expected to strengthen the tech-nological knowledge pool of LSP and bring new opportunities in the future.

WIRE DESIGN & SPECIFICATION

In frame of the FAIR project superconducting NbTi strand with a diameter of 0.8 mm is needed for the manufacturing of Nuklotron type of superconducting cable for dipole and quadrupole magnets. It consists of central Cu-Ni tube around which superconducting strands are wound and fixed with NiCr wire. Several layers of polyimide tape wrapped around the cable as insulation complete the design. [1]. Due to the pulsed operation of the magnets the strand has to fulfill special requirements as small filament diameter to reduce magnetization loop, small twist pitch to minimize eddy current loops and high transverse resistivity to reduce eddy current strength [2,3].

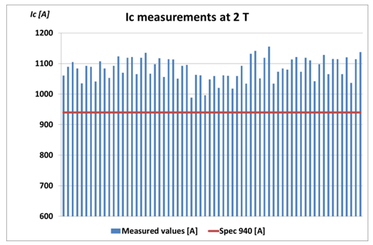
The strand used for the magnets consists of stabilizing OFC copper sheath filled in with superconducting NbTi filaments, each of them is surrounded by Nb barrier and embedded in a resistive CuMn matrix. Both OFC and CuMn alloy material have been produced in-house at Luvata premises in Pori Finland. The manufacturing process is based on using the direct hot extrusion method for the three assembly phases: mono, multi I and multi 2 process steps. The method is known as the double restack manufacturing process.

Altogether over 1000 kilometers of this very demanding ultrafine filament low AC-loss strand has been successfully produced in industrial scale.

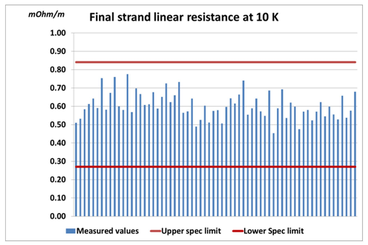
TABLE I
LUVATA DESIGN PARAMETERS FOR NBTI STRAND

Parameter	Unit	
Strand diameter	mm	0.8 +/-0.005
(Cu+CuMn)/NbTi+Nb		1.45 +0.05/-0.1
s/d: interfilamentary spacing		0.127 (nominal)
Filament diameter	µm	3.23 (nominal)
Filament number		24990
Ic at 4.2K, 2T	A	>940
n-value at 4.2K, 2T		>30
Filament twist pitch	mm	6.5 +/-1
Strand linear resistance at 10K	mΩ/m	0.27-0.84
Strand linear resistance at 293K	mΩ/m	63-75
Unit length	m	>500
Effect fil. diameter/Fil. diameter		≤1.5

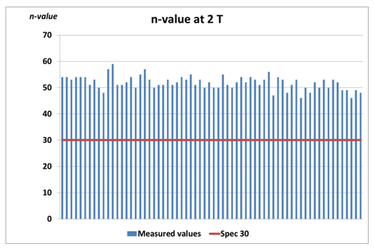
MEASUREMENTS ACCORDING TO SPECIFICATION



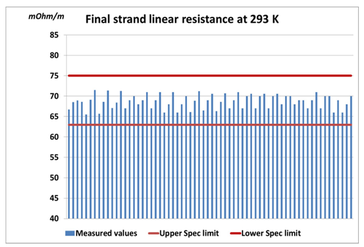
Critical current measurement results at 2T and 4.2 K.



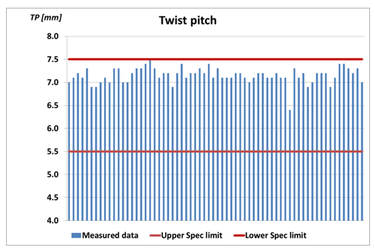
The final strand linear resistance values at 10 K.



n-value measurement results at 2T and 4.2 K.



The final strand linear resistance values at 293 K.



Twist pitch results.

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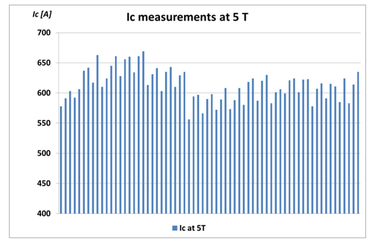
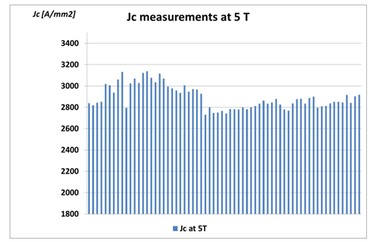
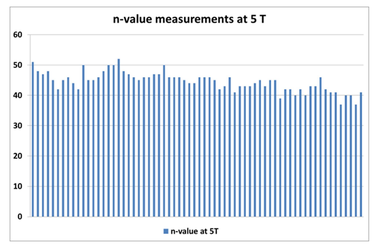
REFERENCE MEASUREMENTS



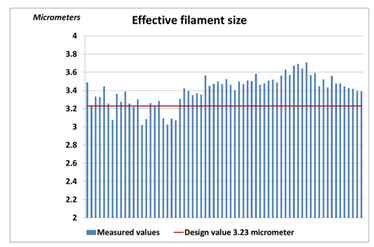
Critical current measurement results at 5T and 4.2 K.



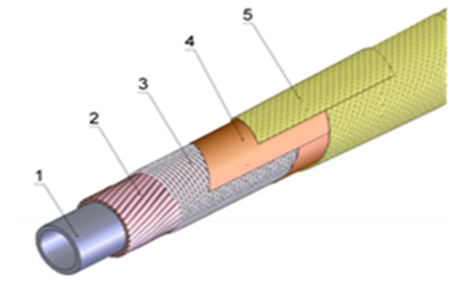
Critical current density calculations at 5T and 4.2 K.



n-value measurement results at 5T and 4.2 K.



Calculated effective filament size of the wire.



1.CuNi -Tube cooled by two-phase forced helium flow
2.Superconducting strands
3.NiCr-wire
4.Kapton foil
5.Glassfaber tape

The design of Nuklotron cable

CONCLUSIONS

All measured values fulfill the specification requirements. Critical current density average value is 2893 A/mm2 at 5T. For this type of ultrafine filamentary wire this performance is excellent throughout the whole industrial scale production. The good n-value together with high critical current density results confirms the uniform filament geometry both vertically and longitudinally. This also refers to good workability of the wire for normal industrial scale production billets.
LSP Superconductors Pori has proven that a low loss NbTi strand with 25000 filaments for the cyclotron SIS100 has been possible to manufacture using in house material for the resistive matrix of CuMn and OFC copper grade. The production has been of industrial scale completing 1030 km of wire in accordance with the agreed schedule and specification.

ACKNOWLEDGMENT

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REFERENCES

[1] H. Muller, E. Floch, GSI Darmstadt Germany, "Technical Specification of Low Loss Superconducting Strand for SIS 100 Main Magnets"

[2] G. Volpini, INFN Milano Italy," Low loss Nb-Ti Superconducting Rutherford Cable Manufacture for the SIS300 INFN Model Di-pole" IEEE Transactions on Applied Superconductivity, Volume: 21, Issue: 3, pp 3334-3337, June 2011

[3] M. N. Wilson et al., "Cored Rutherford Cable for the GSI Fast Ramping Synchrotron", IEEE Trans. Appl. Supercon., vol. 13, no. 2, pp. 1704-1709, 2003.